

**APPLICATION FOR UNITED STATES LETTERS  
PATENT**

**MANUFACTURING METHOD FOR A CERAMIC TO  
METAL SEAL**

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## **MANUFACTURING METHOD FOR A CERAMIC TO METAL SEAL**

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### **FIELD OF THE INVENTION**

This invention relates to a method of producing a hermetically sealed ceramic to metal bond for implantation in living tissue.

### **BACKGROUND OF THE INVENTION**

Known methods of bonding a ceramic to a metal involve the use of interlayer materials which either melt at the bonding temperature, such as a braze, or which involve special coating processes for the material surfaces to be bonded, such as pre-coating the surfaces with an activating material. In some methods of bonding, an interlayer material having a composition that approximates the composition of the initial metal bonding surface is utilized, such as disclosed by Lasater (U.S. Patent No. 6,221,513 B1). Lasater describes a method for forming a hermetically sealed bond for use in implantable medical devices. Hill (U.S. Patent No. 3,594,895) described another approach to forming a ceramic to metal seal.

Cusano (U.S. Patent No. 3,994,430) disclosed a method of directly bonding metal to ceramic substrates wherein a very thin layer of an interlayer material is placed between the metal and the ceramic to be bonded. The system is heated in an inert atmosphere to a temperature between the eutectic temperature of the interlayer material and the melting point of the metal. Cusano focused on bonding copper to a ceramic substrate, such as alumina or beryllia.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**FIG. 1** illustrates the side view of the component assembly with the interlayer material as a foil between the ceramic and metal parts.

**FIG. 2** schematically depicts the bonding steps of the present invention.

## **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

**FIG. 1** shows component assembly 2 having metal part 4, ceramic part 6, and interlayer material 8. Component assembly 2 is heated to a specific process temperature, that is below the melting point of metal part 4, for a specific period of time, at a pressure that is created by force 10 and that is exerted so as to place interlayer material 8 in intimate contact with the metal and ceramic parts.

Interlayer material 8 is a foil having a thickness of less than about two-thousandth of an inch. Interlayer material 8 also is selected from the group of materials that are compatible with the metal chosen for metal part 4. Interlayer material 8 forms a bond with a metal part 4 by virtue of developing a eutectic or close-eutectic alloy at the bonding temperature and pressure utilized during processing. The eutectic alloy formed during processing is composed of the metals selected for metal part 4 and the interlayer material 8. The eutectic alloy formed wets the surface during the bonding process and enters into a diffusion and chemical reaction process with the ceramic part 6 thereby creating a strong bond joint during processing. The group of interlayer materials includes essentially pure nickel, i.e., pure nickel and nickel containing approximately two percent or less by weight of alloy metals. In a preferred embodiment, interlayer material 8 is commercially pure nickel foil having at least 99.0% nickel and less than 1.0% of other elements with a thickness of approximately 0.0007 inches.

Metal part 4 may be a biocompatible material such as a titanium alloy, and is Ti-6Al-4V in a preferred embodiment. Ceramic part 6 may be alumina, titania, zirconia, stabilized-zirconia, partially-stabilized zirconia, tetragonal zirconia, magnesia-stabilized zirconia, ceria-stabilized zirconia, yttria-stabilized zirconia, and calcia-stabilized zirconia, and in a preferred embodiment ceramic part 6 is yttria-stabilized zirconia. In alternative embodiments, rather than using interlayer material 8 as a foil, interlayer material 8 may be a thin coating that is applied to either the metal part 4 or ceramic part 6 surface to be bonded by any of a variety of chemical processes such as electroless plating and electroplating, or by any of a variety of thermal processes such as sputtering, evaporating, or ion beam enhanced deposition. Interlayer material 8 may also be

applied as a thin coating of metallic beads or metallic powder.

The process steps that are employed to create assembly 2 with a strong bond between metal part 4 and ceramic part 6 are schematically represented in **FIG. 2**. First, the surfaces to be bonded are prepared in step 20 by machining to assure that they will intimately conform to each other during bonding. The surfaces are smoothed and cleaned.

In step 22, component assembly 2 is prepared with interlayer material 8 between metal part 4 and ceramic part 6. In step 24, force 10 is applied to compress interlayer material 8 between metal part 4 and ceramic part 6. Force 10 is sufficient to create intimate contact between the parts. Force 10 is applied to assure that a homogeneous bond is formed between metal part 4 and ceramic part 6 thus creating a hermetic seal between the two parts.

In step 26 the assembly to be heat processed is placed in a furnace in a non-reactive atmosphere, which is preferably vacuum, but which can be argon in an alternative embodiment. A vacuum is applied before the furnace is heated to the processing temperature in step 28. A preliminary holding temperature may be used to allow the thermal mass of the parts to achieve equilibrium before proceeding with heating. The process temperature is lower than the melting point of metal part 4, but greater than the temperature of the eutectic formed between metal 4 and interlayer material 8. In a preferred embodiment, the vacuum is  $10^{-6}$  to  $10^{-7}$  torr, to assure that the interlayer material 8 and metal part 4 do not oxidize. Component assembly 2 is held at the selected temperature, which is typically between approximately 1728° and 2012° F, for approximately 1 to 60 minutes, while force 10 continues to be exerted on interlayer material 8. The exact time, temperature and pressure are variable with each other so as to achieve a hermetic and strong bond of metal part 4 with ceramic part 6. For example, in a preferred embodiment, an yttria-stabilized zirconia part is bonded to a Ti-6Al-4V part in vacuum at  $10^{-6}$  torr at approximately 1800° F for 10 minutes with a pressure of approximately 5 to 20 psi on a commercially pure nickel foil of approximately 0.0007 inches thickness.

The furnace is cooled and component assembly 2 is cooled to room temperature

in step 30. In optional step 32, component assembly 2 is cleaned by being placed in a bath, after thermal processing is complete, to assure removal of all nickel and nickel salts. This bath is preferably an acid bath that etches the exposed surfaces of component assembly 2. In a preferred embodiment, the bath is nitric acid. Removal of nickel and nickel salts in the bath etch insures that component assembly 2 is biocompatible. Nickel and nickel salts are detrimental to living animal tissue. In the preferred embodiment, however, all of the nickel that is introduced as interlayer material 8 is combined with the titanium, aluminum and vanadium and is tied up to be unavailable as free nickel or as a nickel salt.

Component assembly 2 is biocompatible after bonding and processing. Metal part 4, ceramic part 6, and interlayer material 8 are selected so as to be compatible with the environment in a living body. Hence, metal part 4 is typically a titanium alloy and ceramic part 6 is typically zirconia.

In a preferred embodiment, component assembly 2 is either an electrical sensor or an electrical stimulator that is implanted in a human body, although it could equally well be implanted in any animal. It must survive long periods in the hostile environment of a living body, which is basically a warm saline solution. In a preferred embodiment, component assembly 2 is either a sensor or stimulator comprised of a hollow ceramic tube that contains various electronic components that is bonded to a metal electrode end. The component assembly must be watertight; hence, the bond is hermetic, resisting salt-water intrusion as well as growth of living tissue into the metal-to-ceramic bond joint.

Further, component assembly 2 does not corrode while implanted in the body. The materials are chosen such that post-bonding they are not susceptible to corrosion either individually or in the as-bonded state. Component assembly 2 resists electrolytic corrosion as well as crevice corrosion, because of the materials selected for component assembly 2.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as

specifically described.